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Early Silurian actinocerid and orthocerid cephalopods from the Kerman area, East-Central Iran

SHUJI NIKO[1], YOSHITAKA KAKUWA[2], DAISUKE WATANABE[3] and RYO MATSUMOTO[3]

[1]*Department of Environmental Studies, Faculty of Integrated Arts and Sciences, Hiroshima University, Higashihiroshima 739-8521, Japan*

[2]*Department of Earth Science and Astronomy, College of Arts and Sciences, University of Tokyo, Komaba 153-0041, Japan*

[3]*Geological Institute, University of Tokyo, Hongo 113-0033, Japan*

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Abstract. Six species of uncoiled cephalopod, including the actinocerids Actinoceratidae, gen. and sp. indet., *Armenoceras banestanense* sp. nov., *A.* sp., *Elrodoceras* sp. and *Huroniella iranica* sp. nov., and an orthocerid Proteoceratidae ?, gen. and sp. indet., are present in collections made recently from an unnamed formation near Banestan village in the Kerman area of southern East-Central Iran. The cephalopod fauna contains forms closely related with those from Laurentia, and is considered to be of Early Silurian age. This discovery reveals that the geologic age of these cephalopod-bearing horizons should be revised from a vague late Ordovician or early Silurian one. These horizons are correlative with the Niur Formation in the Shirgesht area of northern East-Central Iran.

Key words: Actinocerida, cephalopods, Early Silurian, Iran, Orthocerida

Introduction and geologic setting

During the course of field work in February, 1996, several uncoiled cephalopods were discovered by two of us (Y.K. and D.W.) at three localities near Banestan village in the Kerman area of southern East-Central Iran (Figure 1). The purpose of this paper is to document the fauna and to discuss its implications. The specimens are deposited in the University Museum of the University of Tokyo (UMUT).

Until its separation and northward drifting at or near the Permian-Triassic boundary, the Iran terrane belonged to the Gondwana continent, and the Kerman area was part of a carbonate platform around the margin of Gondwana (e.g., Lensch *et al.*, 1984). The geology of the Kerman area has been described by Huckriede *et al.* (1962), Zohrenbakhsh and Vahdati Daneshmand (1992) and Richards *et al.* (1994). These investigatiors discerned three units in the Lower to Middle Paleozoic strata: Upper Cambrian to Lower Ordovician carbonates of the Mila Formation, the Arenig (upper Lower Ordovician) graptolite shale of the Katkoyeh Formation, and an unnamed formation probably ranging from Upper Ordovician to Middle Devonian that mainly consists of clastics with subordinate carbonates. The cephalopods described herein occur in argillaceous and/or bioclastic limestone of the unnamed formation (Figure 2). The cephalopod-bearing horizons have been described as "orthoceras limestone" by Huckriede *et al.* (1962), and regarded as being of late Ordovician or early Silurian age. However, the exact biostratigraphic range of the cephalopod-bearing horizons has so far been a matter of debate.

Detailed analysis of morphologic features of the present cephalopods resulted in the identification of five Early Silurian actinocerid and one orthocerid species that provide insights into the precise age and paleobiogeographic affinities of the fauna. This is the first modern taxonomic treatment of Silurian cephalopods from the Iran terrane.

Systematic paleontology

Subclass Actinoceratoidea Teichert, 1933
Order Actinocerida Teichert, 1933
Family Actinoceratidae Saemann, 1853

Genus and species indeterminate

Figures 3-7, 5-5, 6

Discussion.—A single incomplete specimen of a gently cyrtoconic (?) phragmocone is assigned to the Actinoceratidae, genus and species indeterminate, based on its relatively long and normal cyrtochoanitic septal necks and the high ratio (at least 3.2) of maximum diameter/length of its siphuncular segments.

The restricted development of the annulosiphonate

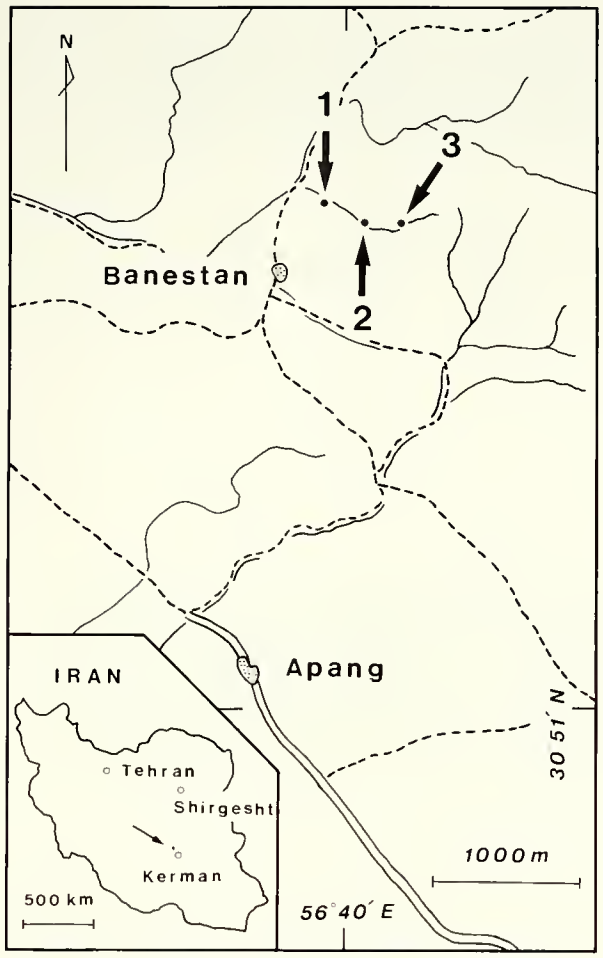


Figure 1. Index map of fossil localities (1–3) in the Kerman area (small arrow in inset), southern East-Central Iran.

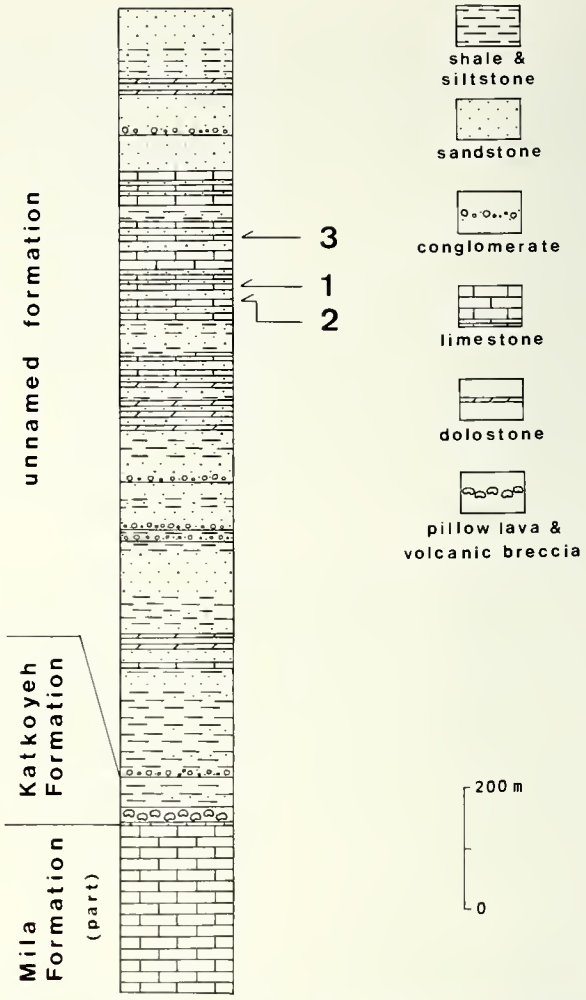


Figure 2. Generalized stratigraphic section of the Lower to Middle Paleozoic rocks near Banestan village in the Kerman area. Stratigraphic horizons of each locality are indicated.

deposits on the ventral siphuncular wall and the straight radial canals projecting to the vicinity of brims are an unusual diagnosis for the family and indicate a possibility that the species represents a new genus. Unfortunately the ventral shell is not preserved in the only specimen available. Until additional material is found, the present material is considered too poor to justify naming it to the generic level.

Material and occurrence.—UMUT PM 27332, 72 mm in length, from locality 3.

Family Armenoceratidae Troedsson, 1926
Genus ***Armenoceras*** Foerste, 1924a

Type species.—*Actinoceras hearsti* Parks, 1913.

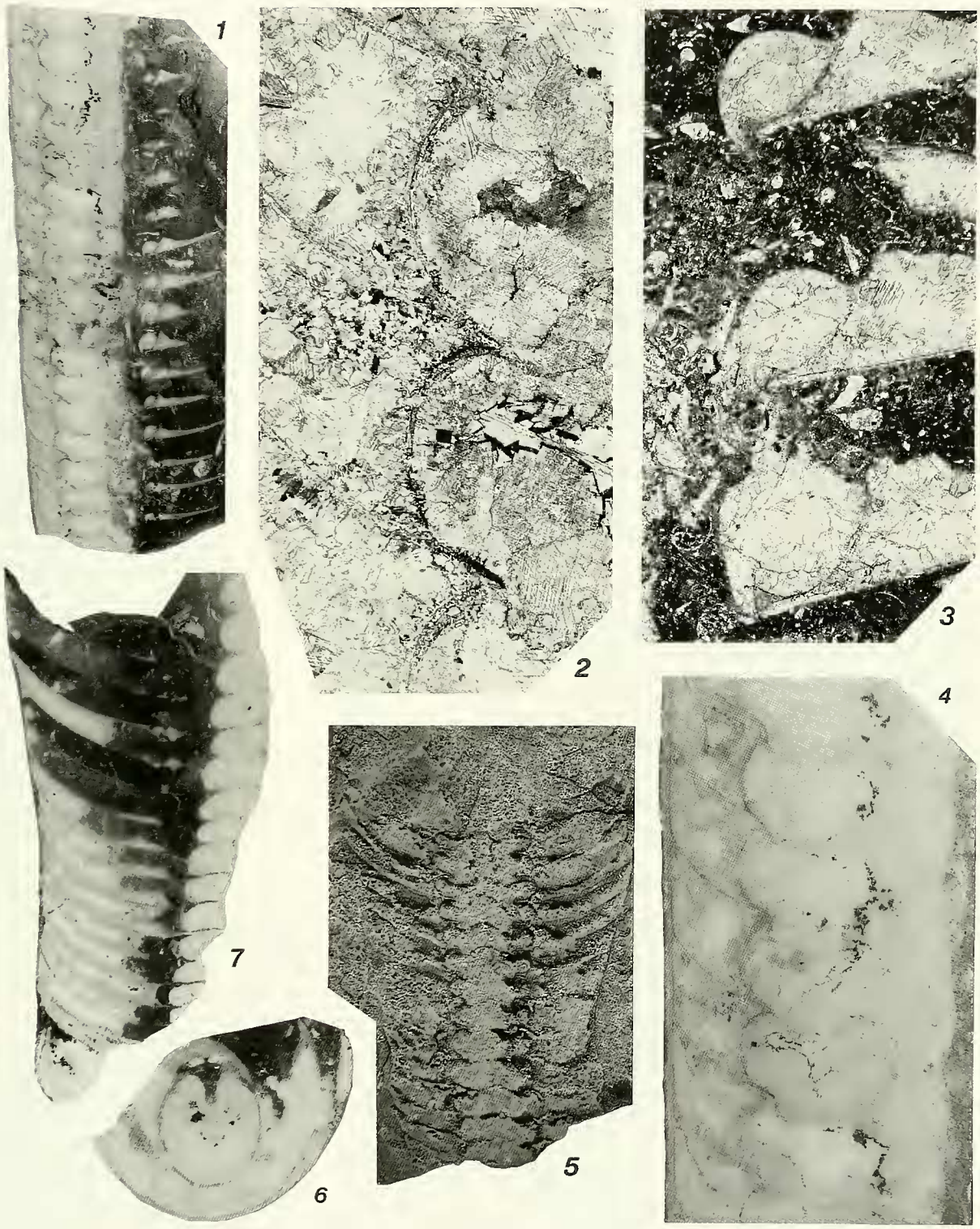
Armenoceras banestanense sp. nov.

Figures 3-1—6

Diagnosis.—*Armenoceras* with smaller ratio of maximum siphuncular diameter to shell diameter (approximately 0.3–0.4), very narrow adnation areas in dorsal siphuncular wall; cameral deposits well developed; central canal situated on dorsal margin.

Description.—Orthoconic shells with circular cross sections, moderate shell expansion for the genus, lacking

Figure 3. 1–6. *Armenoceras banestanense* sp. nov., 1–4, 6: holotype, UMUT PM 27328, 1, dorsoventral thin section, venter on left, ×2, 2, dorsoventral thin section, showing details of ventral wall of siphuncle, ×14, 3, dorsoventral thin section, showing details of dorsal wall of siphuncle, note very narrow adnation area, ×14, 4, dorsoventral thin section, showing details of ventral shell, ×5, 6, transverse thin section of adoral end, venter down, ×2, 5: paratype, UMUT PM 27327, weathered surface of dorsal side, coated with ammonium chloride, ×2. 7. Actinoceratidae, gen. and sp. indet., UMUT PM 27332, dorsoventral thin section, venter on right, ×2.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conspicuous surface ornamentation; adoral end of imperfect phragmocone of holotype attains approximately 25 mm (slightly deformed) in diameter. Septa closely spaced, moderately shallow; siphuncle large, ratio of maximum siphuncular diameter to shell diameter is small for genus, approximately 0.3–0.4, submarginal in position; septal necks very short, 0.15–0.21 mm in length, strongly recurved cyrtochoanitic; brims short for genus, 0.44 mm in well preserved dorsal brim of holotype, in contact with apical surface of septa; diameter of septal foramen 5.9–8.9 mm in holotype; connecting rings broadly expanded; adnation areas moderate to relatively narrow (their length in dorsoventral section approximately 0.9 mm) in ventral siphuncular wall, and very narrow (do. approximately 0.3 mm) in dorsal siphuncular wall; maximum diameter/length ratio of siphuncular segments 3.5–4.0. Cameral deposits well developed, episeptal-mural and forming circumsiphuncular ridges, additional hyposeptal deposits recognized in ventral side of camerae; ventral endosiphuncular deposits fusing to form thick lining on siphuncular wall, differentiated into outer annuli and inner lining deposits; profile of outer annuli laterally elongated elliptical in longitudinal section; development of endosiphuncular deposits on dorsal siphuncular wall weak, separated annuli with semicircular profile in longitudinal section. Central canal situated on dorsal margin, branching off narrow radial canals, of which distal parts are curved adorally; perispatia small, situated near adoral end of each connecting ring.

Discussion.—*Armenoceras banestanense* sp. nov. is most similar to *A. hearsti* (Parks, 1913; 1915, pl. 6, fig. 5; Foerste, 1924a, pl. 13, fig. 4) which has a siphuncular position and a form ratio of the siphuncular segments like the new species. *Armenoceras hearsti* was reported from "Limestone Rapids" on the Severn River, Ontario, Canada, and derived from the Ekwan River or Attawapiskat Formation of late Llandovery (Early Silurian) age (Jin *et al.*, 1993). However the former is distinguishable from the latter by its smaller siphuncle (ratio of maximum siphuncular diameter to shell diameter approximately 0.45 in *A. hearsti* versus 0.3–0.4 in *A. banestanense*), its somewhat weaker inflation of the connecting rings with the narrower adnation area, and the marginal position of its central canal.

The brims of *Armenoceras banestanense* and the cooccurring *A.* sp. (this report) are frequently missing or obscured by diagenesis, thus they are apt to be incorrectly described as "achoanitic".

Material and occurrence.—Holotype, UMUT PM 27328, an incomplete phragmocone, 51 mm in length; paratype, UMUT PM 27327, an incomplete phragmocone, 42 mm in length. Both from locality 3.

Etymology.—The specific name is derived from the village named Banestan near the type locality.

Armenoceras sp.

Figures 4–5, 7, 8

Description.—Orthoconic shells with gradual shell expansion, shell diameter reaches 20 mm at adoral end of largest specimen (UMUT PM 27329). Siphuncle subcentral in position, consisting of strongly recurved cyrtochoanitic septal necks and expanded connecting rings with relatively wide adnation area; brims in contact with septa; maximum diameter/length ratio of siphuncular segments approximately 2.5. Cameral deposits episeptal-mural and hyposeptal; endosiphuncular deposits of annuli have elliptical profile in longitudinal section. Nearly straight radial canals connect with prespatia in apical shell.

Discussion.—This species is easily distinguished from *Armenoceras banestanense* sp. nov. by its subcentral siphuncular position and the smaller form ratio of the siphuncular segments.

Material and occurrence.—Two incomplete phragmocones, UMUT PM 27329, 62 mm in length, and 27330, 61 mm in length, from locality 3.

Genus ***Elrodoceras*** Foerste, 1924b

Type species.—*Cyrtoceras indianense* Miller, 1892.

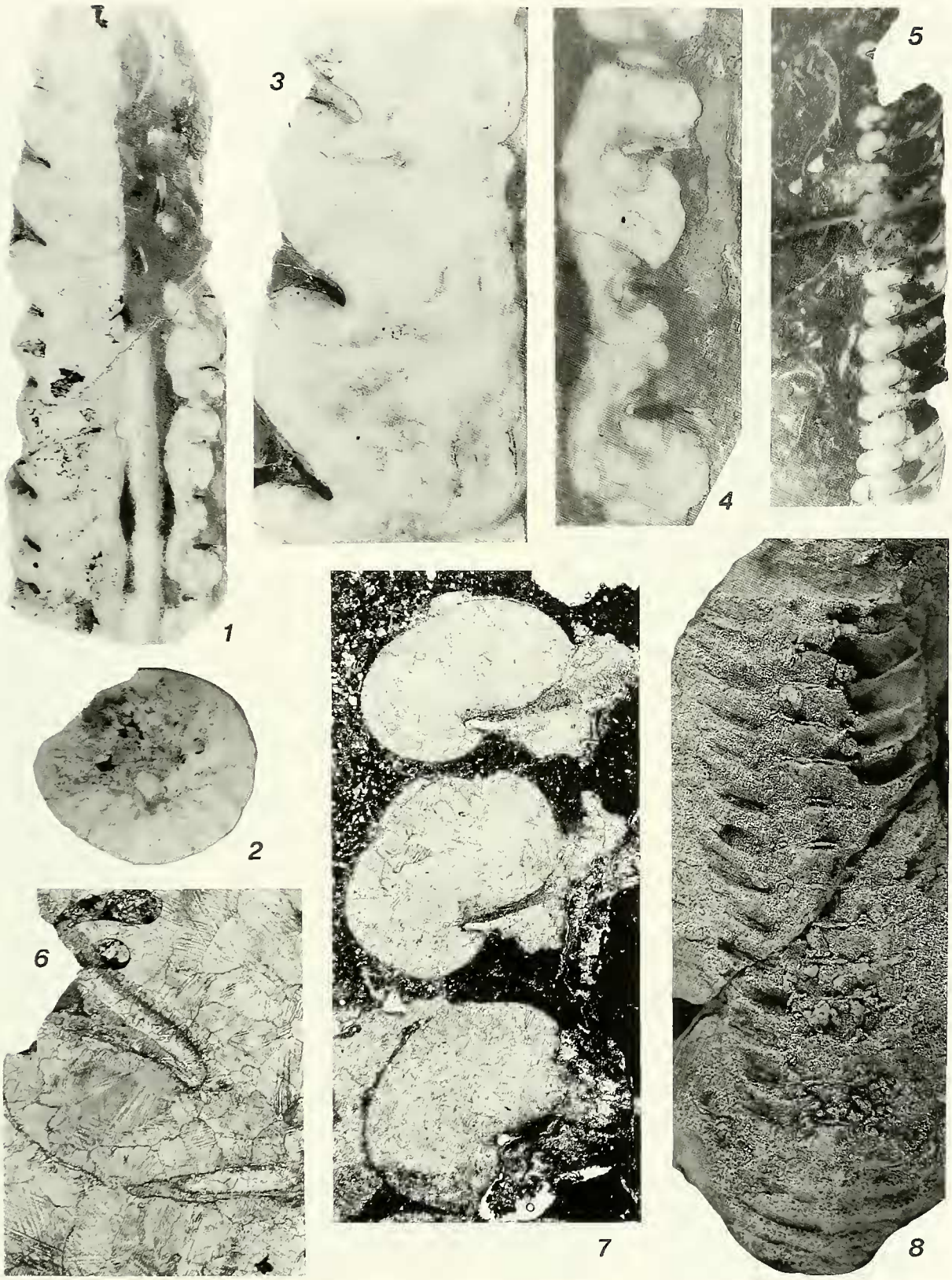
Elrodoceras sp.

Figures 5–1—3

Description.—Siphuncle gently curved (?) and large, attains at least 15.5 mm in maximum diameter, with relatively low ratio of maximum diameter/length in siphuncular segment for armenoceratids, at approximately 2.5–2.7; siphuncular position submarginal (?). Septal necks bend adapically, thus septal foramen is funnel-shaped; brims strongly recurved cyrtochoanitic, in contact with septa; connecting rings form very wide adnation area and moderately inflated free parts. Cameral deposits episeptal-mural and hyposeptal; endosiphuncular deposits well developed, annulosiphonate. Central canal surrounded by lining deposits that are darker in color than annulosiphonate deposits; radial canal arched with branches.

Discussion.—Except for the deposit-filled siphuncle, the shell of this only known specimen is broken and weathered on the dorsum, thus accurate shell shape and siphuncular position can not be determined in the present material. Nevertheless, this species appears most similar to *Elrodoceras* in its siphuncular morphology such as the funnel-shaped

Figure 4. **1–4, 6.** *Huroniella iranica* sp. nov., holotype, UMUT PM 27326, isolated siphuncle, 1, dorsoventral thin section, venter on left, ×2, 2, transverse thin section of apical end, venter down, ×2, 3, dorsoventral thin section, showing details of ventral wall of siphuncle, ×5, 4, dorsoventral thin section, showing details of dorsal wall of siphuncle, ×5, 6, dorsoventral thin section, showing details of septal neck and radial canal in ventral wall of siphuncle, note contact layer and depression on apical surface of septum, ×14. **5, 7, 8.** *Armenoceras* sp., 5, 7: UMUT PM 27330, 5, dorsoventral thin section, venter on right, ×2, 7, dorsoventral thin section, showing details of ventral wall of siphuncle, ×14, 8: UMUT PM 27329, weathered surface of ventral side, coated with ammonium chloride, ×2.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septal foramen, arched radial canals and relatively low form ratio of the siphuncular segments.

Material and occurrence.—UMUT PM 27331, 55 mm in length, from locality 3.

Family Huroniidae Foerste and Teichert, 1930
Genus ***Huroniella*** Foerste, 1924a

Type species.—*Huronia inflecta* Parks, 1915.

Huroniella iranica sp. nov.

Figures 4-1—4, 6

Diagnosis.—*Huroniella* with asymmetrical connecting rings; siphuncular segments short; adoral bending of septa lacking; width of septal foramen/distance of neighboring septal necks 2.3-3.0; perispatia wide, attain distal end of brim.

Description.—Large straight siphuncle, 20.5 mm in lateral diameter of apical end of holotype; septal necks short, approximately 0.5 mm in length, strongly recurved cyrtochoanitic; brims 0.63-0.68 mm in length, in contact with apical surface of septa; diameter of septal foramen 12.5-14.0 mm; shape of connecting rings asymmetrical in dorsoventral section, ventral connecting rings strongly inflated, bluntly pointed arcs with obliquely adoral direction in longitudinal section; adnation area in adoral surface of septa very wide, forming contact layer by thickening of connecting ring; in contrast to adoral surface of septa, relatively narrow in apical surface, contact layer also recognized where septa are weakly depressed; dorsal connecting rings semicircular with narrow adnation area lacking evident contact layer; siphuncular segments short for huroniids, width of septal foramen/distance of neighboring septal necks 2.3-3.0. Endosiphuncular deposits of annuli well developed leaving large central canal in a position slightly shifted from axis; radial canals curving adapically and branching, to join wide perispatia, which attain distal end of brim.

Discussion.—*Huroniella iranica* sp. nov. appears to be most like *H. persiphonata* (Billings, 1857; Foerste, 1927, pl. 44, fig. 1; Teichert, 1933, figs. 4, 20) from the upper Llandovery Jupiter Formation of Anticosti Island, Canada. The Laurentian species shares the asymmetrical profile of its connecting rings with the present new species. The most obvious difference between these species is the septal morphology, i.e., a strong adoral bending of the septum is recognized in *Huroniella persiphonata*, but only a weak depression on the adoral septal surface is representative of *H. iranica*. In addition, the width of septal foramen/distance of neighboring septal necks ratio (approximately 2 in *H. persiphonata* versus 2.3-3.0 in *H. iranica*) is also a diagnostic feature.

Huroniella inflecta (Parks, 1915, pl. 6, fig. 4; Foerste, 1924a, pl. 16, figs. 2a, b; Teichert, 1933, fig. 12), known from the "Limestone Rapids" in Ontario, is distinguished from the present species by having more strongly inflated dorsal connecting rings with a nearly symmetrical profile in dorsoventral section.

Material and occurrence.—Holotype, UMUT PM 27326, an isolated and incomplete siphuncle 65 mm in length, from locality 1.

Etymology.—The specific name in derived from Iran.

Subclass Nautiloidea Agassiz, 1847
Order Orthocerida Kuhn, 1940
Superfamily Pseudorthocerataceae Flower and Caster, 1935
? Family Proteoceratidae Flower, 1962

Genus and species indeterminate

Figures 5-4, 7

Discussion.—The poorly preserved specimen consists of a gradually expanding orthoconic shell with relatively short camerae, subcentral siphuncle consisting of short cyrtochoanitic septal necks and inflated connecting rings. Its maximum diameter/length ratio of siphuncular segments is approximately 1.5, and cameral deposits are episeptal.

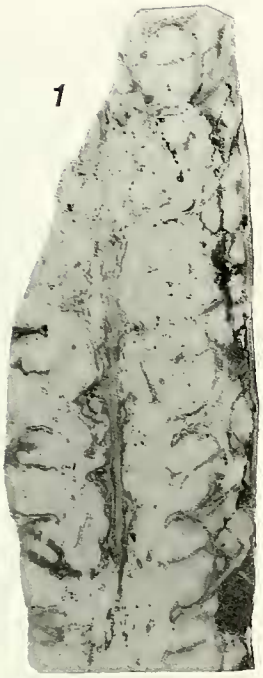
This species probably belongs to the Proteoceratidae, and its large siphuncular segment ratio for an orthocerid suggests a possible relationship with *Ephippiorthoceras*, although the material is insufficiently preserved to identify any further.

Material and occurrence.—Single incomplete phragmocone, UMUT PM 27333, 74 mm in length, from locality 2.

Stratigraphic and paleobiogeographic implications

The cephalopod species recognized at each locality are as follows: locality 1, *Huroniella iranica* sp. nov.; locality 2, Proteoceratidae?, gen. and sp. indet.; and locality 3, Actinoceratidae, gen. and sp. indet., *Armenoceras banestanense* sp. nov., *A.* sp., and *Elrodoceras* sp. The most useful taxon for correlation is *Huroniella*, whose range is known with certainty from late Llandovery to early Wenlock strata in Laurentia and Baltica. Species similar to *Huroniella iranica* are found in the Anticosti Island and Hudson Bay areas and are of late Llandovery age. *Elrodoceras* is the only Silurian cephalopod previously known from Laurentia, Avalonia, Baltica and Siberia. *Armenoceras banestanense* sp. nov. is related to the late Llandovery species *A. hearsti* from the Hudson Bay area, and the genus is cosmopolitan

Figure 5. **1-3.** *Elrodoceras* sp., UMUT PM 27331, 1, dorsoventral thin section, venter on right, ×2, 2, dorsoventral thin section, showing details of ventral wall of siphuncle, ×5, 3, dorsoventral thin section, showing details of septal necks, radial canal and connecting ring in ventral wall of siphuncle, note adapical bending of septal necks, ×14. **4, 7.** Proteoceratidae?, gen. and sp. indet., UMUT PM 27333, 4, longitudinal thin section, ×2, 7, longitudinal thin section, showing details of siphuncle, ×8. **5, 6.** Actinoceratidae, gen. and sp. indet., UMUT PM 27332, 5, dorsoventral thin section, showing details of ventral wall of siphuncle, arrows indicate septal necks, ×14, 6, dorsoventral thin section, showing details of dorsal wall of siphuncle, ×14.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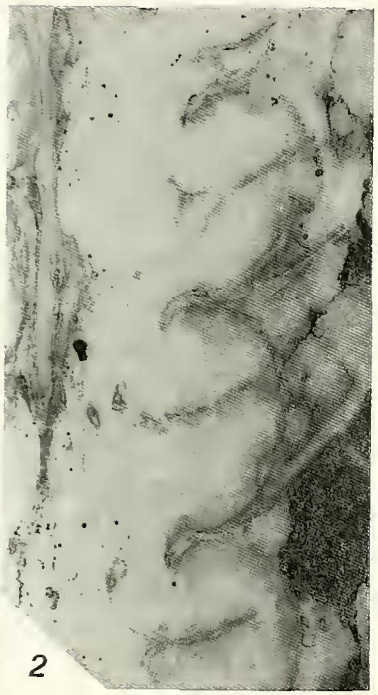
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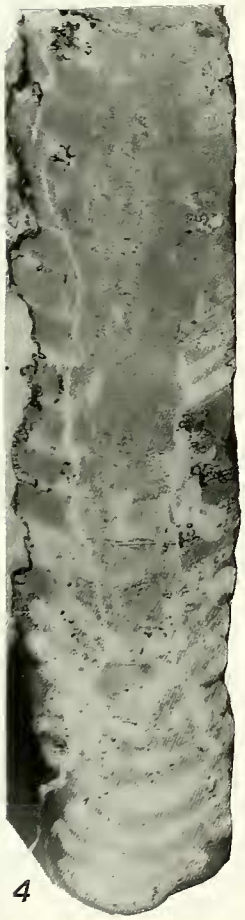
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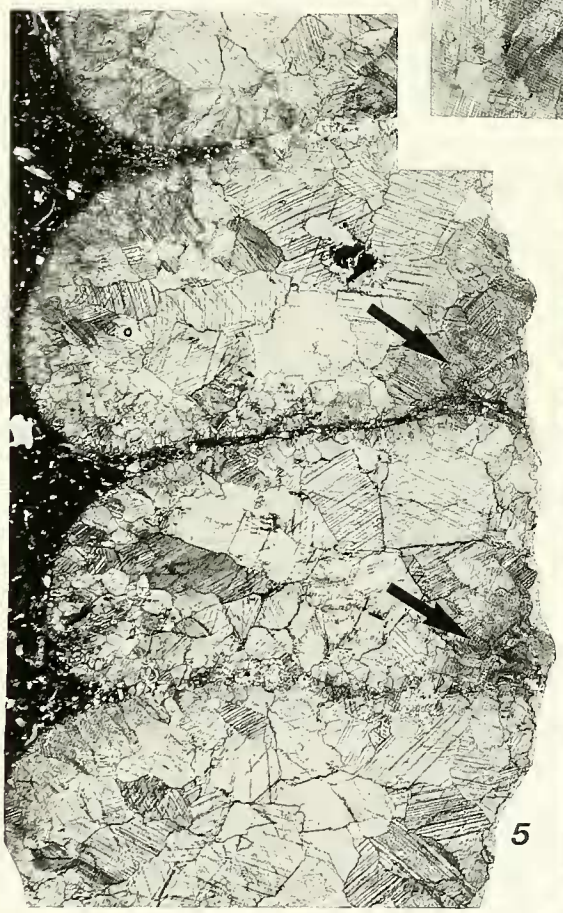
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and ranges from Middle Ordovician to Late Silurian in age. Besides cephalopods, the Wenlockian bryozoan species *Trematopora beikhemensis* is identified by S. Sakagami (personal communication) from locality 1. Although locality 2 lacks a clear age indicator, lithologically the three horizons may belong to a stratigraphic unit without notable breaks. On the basis of this evidence, we infer that at least the cephalopod-bearing horizons in the unnamed formation indicate a late Llandovery (or early Wenlock) age, and are lithologically and chronostratigraphically correlative with the Niur Formation (Ruttner *et al.*, 1968) in the Shirgesht area of northern East-Central Iran. On the other hand, the affinity of the cephalopod fauna is apparently with northeastern Laurentia. This new material suggests a faunal connection between Gondwana and Laurentia during Early Silurian times.

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